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Research Paper

Radon Gas Measurement in the Civil Architecture of the Santa Barbara Castle in Alicante

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ABSTRACT: *The presence of Radon gas in buildings is an indicator of air quality. The present study analyzes the amount of radon gas in the most singular construction of the city of Alicante (Spain): The Castle of Santa Bárbara. These infrastructures are very important for the city due to its historical character. Radon gas is considered to be highly harmful to human beings by different scientific agencies in the field of medicine and health, including the World Health Organization (WHO). The main effect of the presence of Radon in the human environment is the risk of lung cancer. This radioactive gaseous element is present in almost all the building materials, and in the lands in which the buildings are implanted. In Spain, the Technical Building Code (TBC) does not yet contemplate the maximum dose of Radon that one building can house and how to contain it.*

Keywords: *Radon, Healthy Architecture, Building Materials, Environment*

I. INTRODUCTION

Radioactivity is a physical phenomenon by which the unstable isotopes of certain chemical elements are able to lose energy and become other more stable isotopes. The process involves the emission of radiation in the form of electromagnetic waves (X-rays and gamma rays) or particles (alpha, beta and neutrons). This type of radiation is called ionizing because when it penetrates matter, it usually pulls electrons from the surrounding atoms by a process known as ionization. If the material is biological tissue with a high-water content, the ionization of water molecules can give rise to so-called free radicals that have a high chemical reactivity, sufficient to alter important molecules that are part of the tissues of living beings. These alterations may include chemical changes in DNA, the basic organic molecule that is part of the cells that make up our body [1]. These changes can lead to the appearance of biological effects, including the abnormal development of cells[2]. These alterations can be more or less severe depending on the dose of radiation received [3]. Three quarters of the radioactivity in the environment comes from the natural elements. In this sense, radon is the major source of natural radioactivity (Fig. 1) and the public health problem generated by its concentration and that of its descendants in drinking water or in the interior of the buildings has made people aware of that what has hitherto been considered a despicable fund has, at least, to be determined for its correct evaluation [4]. Radon gas is produced as a result of the disintegration of the uranium and thorium contained in the rocks. The amount of this gas that accumulates in a building depends on its situation, the materials that have been used in its construction and our way of life (ventilation and time in a stay). Radon emanates from rocks and concentrates in enclosed places, so it is highly recommended that homes and workplaces are properly ventilated[5].

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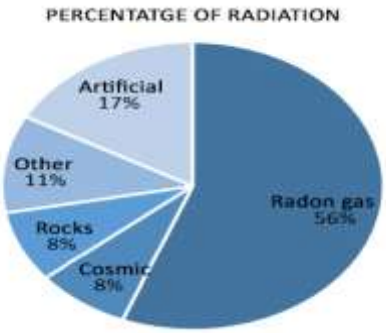

Figure 1. Percentage of radioactivity in the environment.

Radon concentrations in a building vary substantially with the geographical location. Given the large number of factors involved, it is very difficult to predict whether the levels of this gas will be raised in a particular dwelling; on the other hand, it is possible to make reliable predictions about the areas where there is a greater probability of finding houses with high concentrations.

II. MEASUREMENT OF RADON GAS ON MOUNT BENACANTIL

This study presents the results of the Radon gas content in one of the most important geographical points of the city of Alicante: Monte Benacantil, where the elements of the study are located; The Castle of Santa Bárbara. Radon gas measurement in these three dependencies of Monte Benacantil is interesting because of its different typology, both temporal and constructive. The city of Alicante is in a lithological zone with low presence of uranium and thorium, which are the two gas formation chains, is considered of low potential in gas content Radon according to the predictive map MARNA of gas content Radon in Spain [6]. The Monte Benacantil, by its position, is the most important point of the urban nucleus of Alicante, being in a privileged zone for its proximity to the sea and to have a height of approximately 166 meters where the Castle of Santa Barbara is located, being this the construction of the urban center. This fortification is the most important historical construction of the city of Alicante, which served as a defense for the city in medieval times, because of its height and great view of the panorama. In its origins, this construction was surrounded by a wall, for the protection of its inhabitants, which has changed during the passage of the years due to the different armies that have guarded the fort. The slopes of Monte Benacantil range from 15% to 90%, due to the high resistance of calcareous sandstones (San Julián stone), due to its type of rock, it suffers different phenomena of instability on its slopes such as slip of calcarenites on the marls lower rocks, individualized rock fall from the solid front caused by the tectonic activity, instability by overturning by the families of discontinuous rocks parallel to each other and avalanches of rocks aggravated by the explosion of the mine, historical fact that took place in February of 1709 within Of the context of one of the conflicts that occurred in the area.

III. THE CASTLE OF SANTA BARBARA

At the top of Mount Benacantil is the Castle of Santa Bárbara, the most important historical work of the city of Alicante. This fort was conquered by the infant Alfonso X El Sabio to the Arabs the 4 of December of 1248, day of the celebration of Santa Bárbara. In 1296, after several disputes for his property, he is received by the Crown of Aragon and ordered his remodeling. There are many kings who have since ordered renovations that modify the aesthetics of the castle, until Felipe II King performs the last important that lasts at present and since then has only been the object of conservation work. These works lasted between 1562 and 1580, with projects by Juan Bautista Antonelli and Jorge Palearo "El Fratín". The city of Alicante has been attacked at different times, which has also affected the preservation of the castle: in 1691, it suffers some bombings, provoked by the French army, that affect the whole enclosure; In the War of Succession during the period 1706 - 1709, the castle is in the power of the english and suffers great damages; and the military action that caused the most damage to the fortification was in 1873 when the armored frigate "Numancia", in the hands of rebellious nationalists of Cartagena, launched a bombing on the city of Alicante. In 1963, it was open to the public after many years of abandonment and wear and tear during the Spanish Civil War. The castle was endowed with two elevators to 204 meters of depth from the Avenue Jovellanos, parallel to the walk of the Postiguet, to facilitate the ascent to the mountain with a height of 142 meters. Fig. 2 shows the Monte Benacantil dominated by the Castle of Santa Bárbara from the Serra Grossa Mountain located in the north of Alicante.

Figure 2. Image of the north face of Monte Benacantil

IV. METHODOLOGY

The study of the air quality carried out in the three dependencies of Monte Benacantil with the Radon gas as an indicator was performed using an Electrete Ionic Chamber Meter (EICM), a system that combines a camera with a device that works at the same time as generator of an electric field and sensor. Fig. 3 shows the elements used in each of the zones measured in the study. Sampling of the amount of Radon gas was started in December 2015 and had a different duration for each of the selected sites, and was completed in July 2016. For the choice of measurement sites, two basic premises: closed rooms with little ventilation and the possibility of remaining without traffic of people during the days of measurement. The deposit of the elements had to be adapted to the needs of the places and their custodians. The different constructive elements studied on the Castle of Santa Bárbara, have very different ventilation and use conditions, each using the appropriate measurement method within the camera system electrete ionic. The places chosen for each of the places and how to use the equipment were previously analyzed, establishing the type of camera and electrete (short or long time) more appropriate in each case according to the possibilities of time available and the use of the installation.

Figure 3. Image showing the equipment used during the study. The elements that compose it are the meter, a tamper-resistant case, a short-time camera, a long-time camera, a short (blue) and a long (red) electret.

In Fig. 4, we show the different dependencies studied within the Castle of Santa Barbara, each one being different in both construction and ventilation conditions.

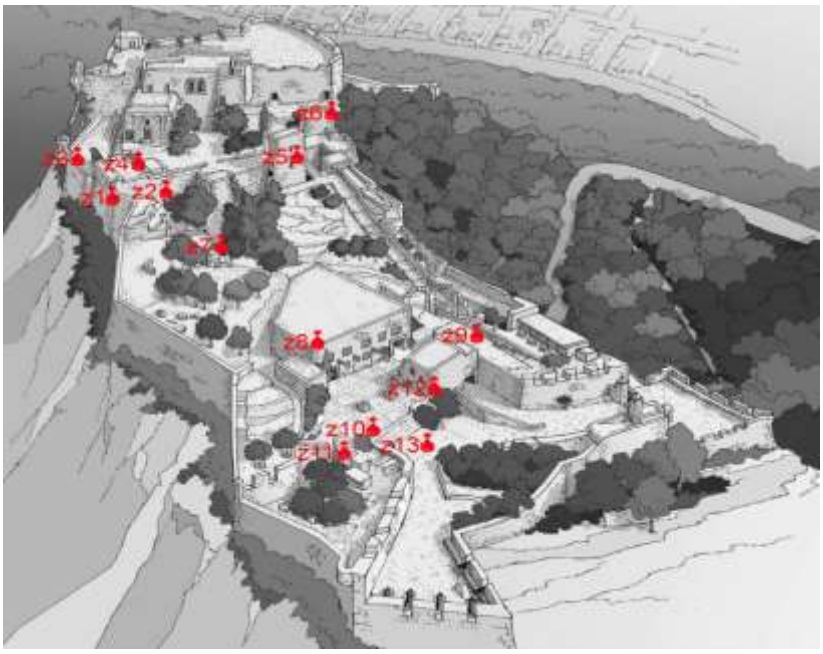

Figure 4. Image of the castle with the location of the cameras in the studio from an image of the Alicante Town Hall. The places of measurement are as follows: (z1) Administration warehouse, (z2) Administration, (z3) Raval Roig, (z4) Elevator Room, (z5) Santa Catalina Tower, (z6) Sant Jordi Tower, (Z8) Powder building, (z9) Felipe II showcase, (z10) Dungeon, (z11) Corridor adjacent to dungeon, (z12) Video room, (z13) Cistern.

V. RESULTS

The results obtained in the different phases of data collection have been expressed for this article by making a mean among all the samples obtained in each of the places. In the rooms of the castle, the construction and measurement conditions are very diverse, due to the concrete needs of each one of them and therefore the results obtained vary a lot since the renovation of air inside each one of these places is very different. The zone with the highest value obtained each time it was analyzed is the zone of administration (Zone 1 and 2), being tested 8 times in different conditions for the verification of the results. This part of the study was very interesting for further verification because of the different accumulation of Radon gas in the same closed room according to the zone [7]. All results are shown in Table 1.

Table 1. Summary measurements made in Castle of Santa Bárbara.

SUMMARY OF MEASUREMENT IN THE CASTLE OF SANTA BÁRBARA			
Place		Samples	Radon (Bq/m^3)
Zone 1	Administration warehouse	8	647,09
Zone 2	Administration	3	252,63
Zone 3	Raval Roig	2	152,66
Zone 4	Elevator room	2	65,97
Zone 5	Tower of Santa Catalina	2	59,25
Zone 6	Tower ofSant Jordi	2	43,93
Zone 7	Powder building	3	86,23
Zone 8	Felipe II showcase	2	189,00
Zone 9	Oven	3	142,25
Zone 10	Dungeon	3	235,46
Zone 11	Corridoradjacent todungeon	1	160,70
Zone 12	Video room	2	111,79
Zone 13	Cistern	1	35,74

VI. DISCUSSION OF RESULTS

The results obtained in the different measurements are compared with the 400 Bq/m^3 recommended not to exceed in 1990 the European Commission for Atomic Energy [8], and the 100 Bq/m^3 of exposure to residential Radon Which was recommended by the WHO in the 2009 Handbook on Indoor Radon publication [9]. At present, the incidence of Radon gas in people is still being studied, in order to establish gas values and under what conditions improvement measures must be taken. In order to extract the results of the study, the two previously mentioned values are considered, considering those less than 100 Bq/m^3 normal, between 100 and 400 Bq/m^3 to be taken into account and those higher than 400 Bq/m^3 places in which Should intervene [10]. For the representation of the results, a comparative graph of the mean value of Radon gas by zones in Bq/m^3 (Fig.s 5) is made from the summary tables of each place studied. The results obtained inside the castle show values below 400 Bq/m^3 in all cases except in the administration warehouse (Zone 1), a totally closed room that is located in the interior of Monte Benacantil, to which Access through the administration room, with a high value of Radon gas, higher than 250 Bq/m^3. Therefore, the store should be considered as a susceptible area, with some type of mechanical ventilation that renews the air (Fig. 5). The rooms between 100 and 400 Bq/m^3 are the video room (Zone 12), the corridor zone adjacent to the dungeon (Zone 11), the dungeon (Zone 10), the oven (Zone 9), the Showcase of Felipe II (Zone 8), Raval Roig (Zone 3) and the administration room (Zone 2). In these places, the content of Radon is high, but immediate intervention is not considered necessary, that is, values must be taken into account and controlled. The rest of the studied sites have mean values lower than 100 Bq/m^3 and do not need to intervene in them: cistern (Zone 13), dustbin (Zone 7), tower of Sant Jordi (Zone 6), tower of Santa Catalina), and elevator room (Zone 4).

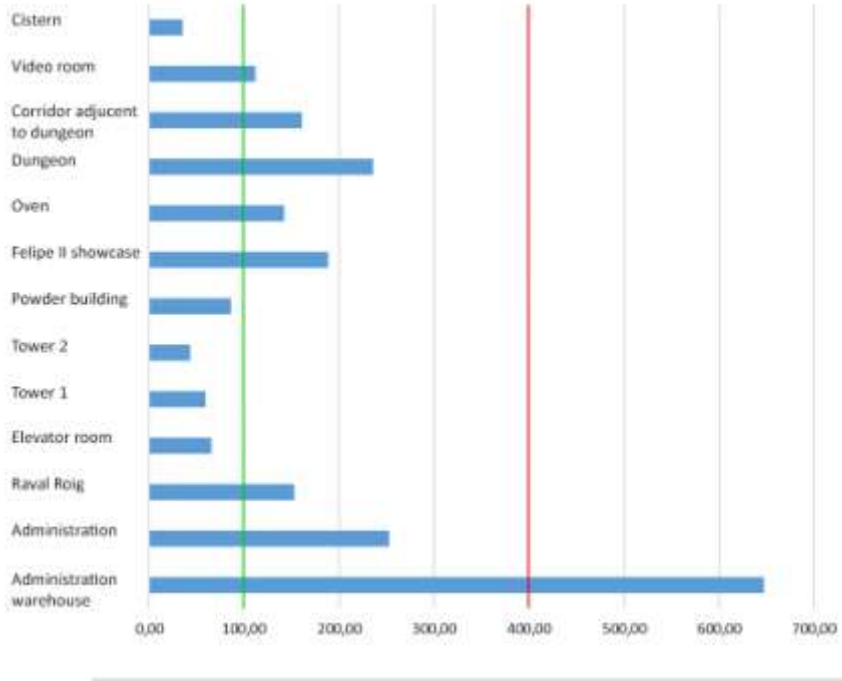

Figure 5. Comparative bar graph of the results obtained inside the different stays of the Castle of Santa Bárbara, measured in Bq/m^3. In reference green of 100 Bq/m^3, in red reference of 400 Bq/m^3.

VII. CONCLUSIONS

In view of the results presented in this work, the need and compliance of ventilation measures to contain the presence of Radon gas in the building, especially in closed spaces used by people, is verified. As is reflected in Technical Report 38.2013 of the Nuclear Safety Council [10], radiological studies on exposures to radon in underground work and leisure places should be compulsory (Including public car parks, mines, metro, museums, tourist caves, etc.). All this regardless of the type of rock on which settle the buildings and the type of materials used. Radon gas is harmful to human health becoming a highly carcinogenic element and therefore, the new construction regulations are working to incorporate this point as a control element. The largest source of this gas is the land, with buildings with low protection measures or underground being able to accumulate larger amounts of this gas. The new constructive forms make the buildings more and more hermetic and prevent the renewal of the air. Other factors to take into account are the temperatures when they are extreme since they facilitate the accumulation of the gas by the difference of pressure and the precipitations that facilitate the ionization of the places. The Monte Benacantil with 166 meters of height is the most important point of the urban nucleus of Alicante, by its visibility of all the coast. At the top of the hill is the Castle of Santa Bárbara, one of the most important historical works of the province. In the Castle of Santa Barbara were analyzed several areas of which only measures to improve ventilation in the administration area should be taken since the accumulation of Radon gas in its interior exceeds 400 Bq/m^3 that is established as reference level Maximum from which to initiate actions of remedy in the already existing constructions. The line of work in which this article is framed reinforces the need to incorporate into the Spanish building regulations (CTE) protocols and standards for radon control.

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REFERENCES

[1]. United Nations. Scientific Committee on the Effects of Atomic Radiation., *Sources and effects of ionizing radiation : United*

Nations Scientific Committee on the Effects of Atomic Radiation : UNSCEAR 2000 report to the General Assembly, with scientific annexes. United Nations, 2000.
[2]. R. Barbosa-Lorenzo, A. Ruano-Ravina, S. Cerdeira Caramés, and J. M. Barros-Dios, "Radón residencial y cáncer de pulmón. Un estudio ecológico en Galicia," *Med. Clin. (Barc).*, vol. 144, no. 7, pp. 304–308, Apr. 2015.
[3]. Consejo de Seguridad Nuclear, *Dosis de Radiación*. Editor Consejo de Seguridad Nuclear, 2010.
[4]. J. L. Llerena Cristobo, *Medición de la concentración de gas 222Rn en el interior de edificios*. USC. Departamento de Física de las Partículas, 2006.
[5]. M. Olaya and F. Borja, "El Código Técnico de la Edificación en España (CTE) Medidas correctoras destinadas a frenar la entrada de radón en los edificios . Investigación de campo como experiencia piloto en España," 2007.
[6]. E. Suarez Mahou, J. Á. Fernández Amigot, A. Baeza Espasa, M. C. Moro Bonito, J. Moreno del Pozo, and J. M. Lanaja del Busto, *Proyecto Marna (Mapa de radiación gamma natural en España).* Editor Consejo de Seguridad Nuclear, 2000.
[7]. G. Mentes and I. Eper-Pápai, "Investigation of temperature and barometric pressure variation effects on radon concentration in the Sopronbánfalva Geodynamic Observatory, Hungary," *J. Environ. Radioact.*, vol. 149, pp. 64–72, 2015.
[8]. 90/143/EURATOM, "Recomendación de la comisión EURATOM, de 21 de febrero de 1990, relativa a la protección de la población contra los peligros de una exposición al radón en el interior de edificios," 1990.
[9]. H. Zeeb, F. Shannoun, and W. H. Organization, "WHO handbook on indoor radon: a public health perspective," 2009.
[10]. M. García-Talavera San Miguel, J. L. Martín Matarranz, R. Gil de Mingo, J. P. García Cadierno, and E. Suárez Mahou, *El mapa predictivo de exposición al radón en España*. Editor Consejo de Seguridad Nuclear, 2013.